Elektrobit

UDACITY

Functional Safety Concept Lane Assistance

Document Version: 1.0

Template Version 2.0, Released on 2017-10-17

Document History

Date	Version	Editor	Description
2017-10-16	1.0	Daniel Gattringer	Initial version

Table of Contents

Document History **2**

Table of Contents **2**

1. Purpose of the Functional Safety Concept **3**

2. Inputs to the Functional Safety Concept **3**

2.1. Safety goals from the Hazard Analysis and Risk Assessment *3*

2.2. Preliminary Architecture *4*

3. Functional Safety Concept **5**

3.1. Functional Safety Analysis *5*

3.2. Functional Safety Requirements *6*

3.3. Refinement of the System Architecture *9*

3.4. Allocation of Functional Safety Requirements to Architecture Elements *11*

3.5. Warning and Degradation Concept *12*

1. Purpose of the Functional Safety Concept

The creation of a functional safety concept is part of the safety process of ISO 26262 for the treatment of potential malfunctions in electrical and electronic systems.

From the safety goals, functional safety requirements are derived on system level and assigned to the higher-level system diagrams.

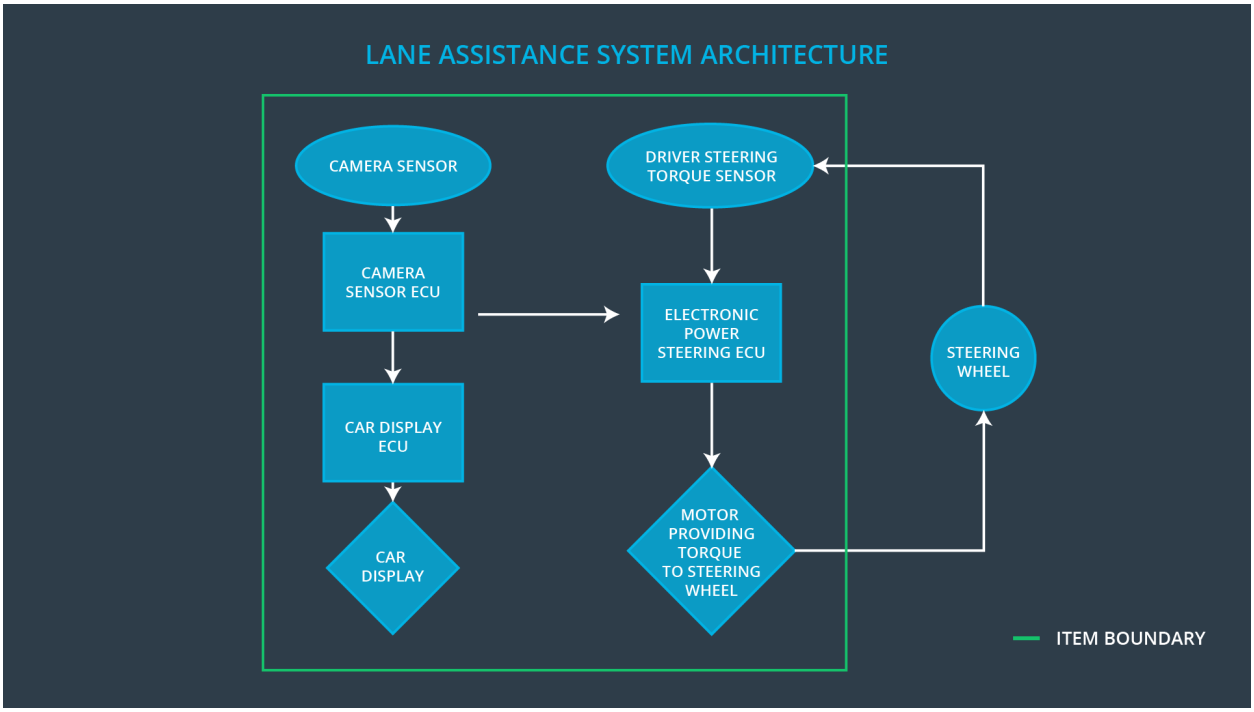
2. Inputs to the Functional Safety Concept

2.1. Safety goals from the Hazard Analysis and Risk Assessment

ID	Safety Goal
Safety_Goal_01	The oscillating steering torque from the lane departure warning function shall be limited.
Safety_Goal_02	The lane keeping assistance function shall be time limited and the additional steering torque shall end after a given time interval so that the driver cannot misuse the system for autonomous driving.
Safety_Goal_03	The lane departure warning function is designed to prevent it from being activated independently if this is not the intention of the driver.
Safety_Goal_04	The lane keeping assistance function shall deactivate itself and shall warn the driver if it is unable to reliably detect lane and road boundaries.

2.2. Preliminary Architecture

The following image shows the preliminary architecture, which will be refined within this document:



Description of architecture elements

Element	Description
Camera Sensor	Sensor for the optical detection of the front area of the vehicle, including detectable lane lines.
Camera Sensor ECU	Electronic Control Unit (ECU) responsible for detecting lane lines and determining when the vehicle leaves the lane by mistake. Responsible for triggering reactions to add extra torque for LDW and LKA functionality.
Car Display	Visual display which is, among other functionalities, responsible for displaying warning of lane departures and displaying LKA and LDW status.
Car Display ECU	Electronic Control Unit (ECU), which is responsible for creating and providing the data and information that the car display visualizes.
Driver Steering Torque Sensor	Sensor responsible for measuring the steering torque provided by the driver.
Electronic Power Steering ECU	Electronic Control Unit (ECU) responsible for evaluating the torque provided by the driver and for

	adding an additional torque based on the torque request of the lane assist system (LKA). Initializes the vibration of the steering wheel when the driver inadvertently drifts away from the center of the lane (LDW).
Motor	Mechatronic device which adds extra steering torque directly to the steering wheel.

3. Functional Safety Concept

The functional safety concept consists of:

- Functional safety analysis
- Functional safety requirements
- Functional safety architecture
- Warning and degradation concept

3.1. Functional Safety Analysis

Malfunction ID	**Main Function of the Item Related to Safety Goal Violations**	**Guidewords (NO, WRONG, EARLY, LATE, MORE, LESS)**	**Resulting Malfunction**
Malfunction_01	Lane Departure Warning (LDW) function shall apply an oscillating steering torque to provide the driver a haptic feedback	MORE DV04 - Actor effect is too much (torque amplitude)	The lane departure warning function applies an oscillating torque with very high torque amplitude (above limit).
Malfunction_02	Lane Departure Warning (LDW) function shall apply an oscillating steering torque to provide the driver a haptic feedback	MORE DV04 - Actor effect is too much (torque frequency)	The lane departure warning function applies an oscillating torque with very high torque frequency (above limit).
Malfunction_03	Lane Keeping Assistance (LKA) function shall apply the steering torque when active in order to stay in ego lane	NO DV03 - Function always activated	The lane keeping assistance function is not limited in time duration which leads to misuse as an autonomous driving function.

Malfunction_04	Lane Departure Warning (LDW) function shall apply an oscillating steering torque to provide the driver a haptic feedback	WRONG DV02 - Function unexpectedly activated	The lane departure warning function is activated independently. The steering wheel begins to oscillate during normal city driving even if the driver expects the system to be deactivated.
Malfunction_05	Lane Keeping Assistance (LKA) function shall apply the steering torque when active in order to stay in ego lane	WRONG DV19 - Sensor detection is wrong	The lane keeping assistance system is activated but the system can't detect the lane boundaries correctly because of snow. The systems interpret the lane boundaries wrong and tries to steer off the road.

3.2. Functional Safety Requirements

Lane Departure Warning (LDW) Requirements:

ID	Functional Safety Requirement	ASIL	Fault Tolerant Time Interval	Safe State
Functional Safety Requirement 01-01	The lane keeping item shall ensure that the lane departure oscillating torque amplitude is below Max_Torque_Amplitude.	C	50ms	Set the oscillating torque to zero.
Functional Safety Requirement 01-02	The lane keeping item shall ensure that the lane departure oscillating torque frequency is below Max_Torque_Frequency.	C	50ms	Set the oscillating torque to zero.
Functional Safety Requirement 03-01	The lane keeping item shall ensure that the lane departure warning by means of vibration of the steering wheel is only possible when LDW_On is set.	A	50ms	Set the oscillating torque to zero.

Lane Departure Warning (LDW) Verification and Validation Acceptance Criteria:

ID	Validation Acceptance Criteria and Method	Verification Acceptance Criteria and Method
Functional Safety Requirement 01-01	Validate that Max_Torque_Amplitude is chosen high enough that the driver notices it but low enough not to cause loss of steering.	Verify that the system really sets oscillating torque to zero if the lane departure warning ever causes a vibration above Max_Torque_Amplitude.
Functional Safety Requirement 01-02	Validate that Max_Torque_Frequency is chosen high enough that the driver notices it but low enough not to cause loss of steering.	Verify that the system really sets oscillating torque to zero if the lane departure warning ever causes a vibration above Max_Torque_Frequency.
Functional Safety Requirement 03-01	Validate that the lane departure warning functionality is never available when it is not activated by the driver.	Verify that the system really sets oscillating torque to zero LDW_On is not set.

Lane Keeping Assistance (LKA) Requirements:

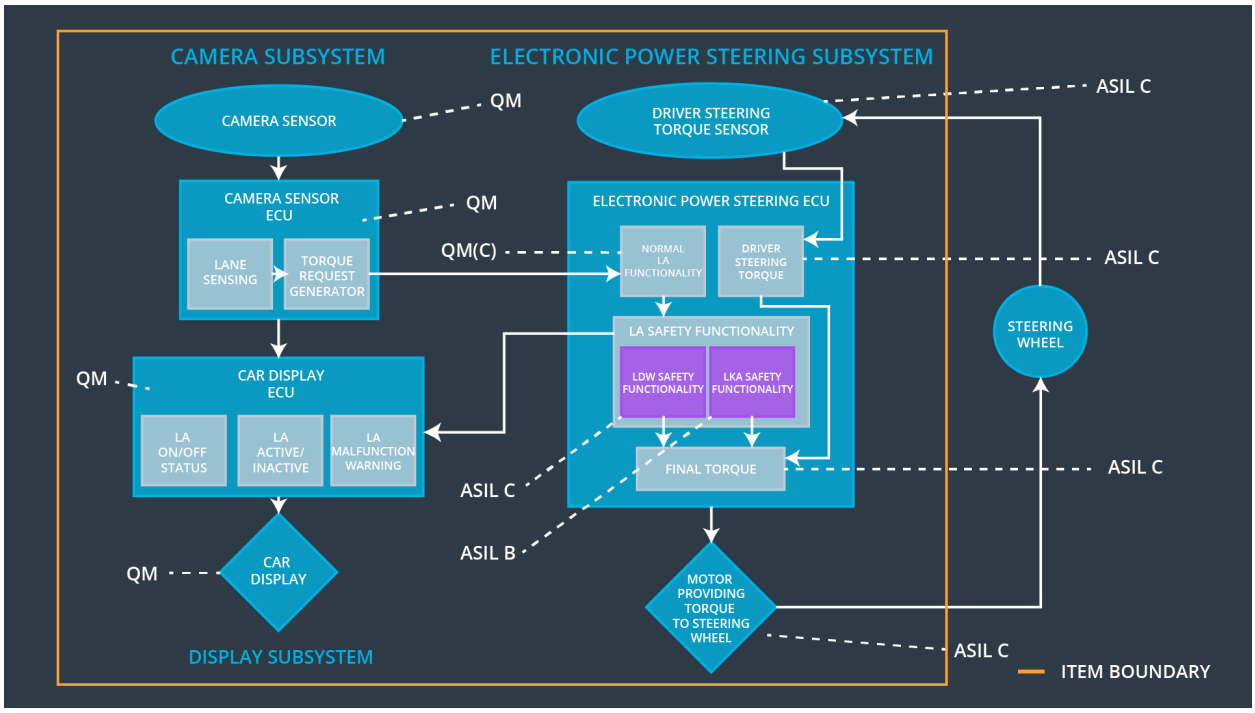
ID	Functional Safety Requirement	ASIL	Fault Tolerant Time Interval	Safe State
Functional Safety Requirement 02-01	The electronic power steering ECU shall shall ensure that the duration of the lane keeping assistance torque applied is less than Max_Duration.	B	500ms	Set the lane keeping add extra torque to zero.
Functional Safety Requirement 04-01	The electronic power steering ECU shall ensure that the lane keeping assistance torque is set to zero when the camera sensor ECU can't reliably detect the lane boundaries.	A	50ms	Set the lane keeping add extra torque to zero.
Functional Safety Requirement 04-02	The electronic power steering ECU shall ensure that the lane keeping assistance functionality is deactivated and signalized on the car display when the camera sensor ECU can't reliably detect the lane boundaries.	A	50ms	Set the lane keeping add extra torque to zero.

Lane Keeping Assistance (LKA) Verification and Validation Acceptance Criteria:

ID	Validation Acceptance Criteria and Method	Verification Acceptance Criteria and Method
Functional Safety Requirement 02-01	Validate that the chosen amount for Max_Duration really dissuades drivers from taking their hands off the wheel.	Verify that the system really sets the lane keeping add extra torque to zero if the lane keeping assistance ever exceeds Max_Duration.
Functional Safety Requirement 04-01	Validate that the lane keeping assistance is not applying extra torque when the lane boundaries are not detected reliably.	Verify that the system really sets the lane keeping add extra torque to zero if the lane boundaries are not detected reliably.
Functional Safety Requirement 04-02	Validate that the lane keeping assistance is warning via car display when the lane boundaries are not detected reliably while the system is active.	Verify that the system really warns the driver via the car display if the lane boundaries are not detected reliably.

3.3. Refinement of the System Architecture

The following image shows the refined system architecture:



Description of architecture elements

Element	Description
Camera Sensor	Sensor for the optical detection of the front area of the vehicle, including detectable lane lines.
Camera Sensor ECU	Electronic Control Unit responsible for detecting lane lines and determining when the vehicle leaves the lane by mistake. Responsible for triggering reactions to add extra torque for LDW and LKA functionality.
Camera Sensor ECU Lane Sensing	Component within the camera sensor ECU responsible for detecting lane lines and determining when the vehicle leaves the lane by mistake.
Camera Sensor ECU Torque Request Generator	Component within the camera sensor ECU responsible for calculating and sending an request for additional steering torque for the LDW and LKA functionality.
Car Display	Visual display which is, among other functionalities, responsible for displaying warning of lane departures and LKA and LDW activation-status.
Car Display ECU	Electronic control unit, which is responsible for creating and providing the data and information that the car display visualizes.

Car Display ECU LA on/off status	Component within the car display ECU responsible for visualizing if the lane assistance functionality is switched on or off.
Car Display ECU LA active/inactive	Component within the car display ECU responsible for visualizing if the lane assistance functionality is active at the moment. Active means the car is drifting away from the center of the lane and LKA is actively acting or the car is getting too narrow to a lane boundary and LDW is warning.
Car Display ECU LA malfunction warning	Component within the car display ECU responsible for visualizing if there occurs any malfunction within the lane assistance system.
Driver Steering Torque Sensor	Sensor responsible for measuring the steering torque provided by the driver.
Electronic Power Steering (EPS) ECU	The electronic control unit is responsible for evaluating the torque provided by the driver and for adding an additional torque based on the torque request of the lane assist system (LKA). Initializes the vibration of the steering wheel when the driver inadvertently drifts away from the center of the lane (LDW).
EPS ECU Normal Lane Assistance Functionality	Component within the electronic power steering ECU responsible for receiving extra torque request from the camera sensor ECU and doing different non-safety tasks.
EPS ECU Driver Steering Torque	Component within the electronic power steering ECU responsible for receiving the steering torque with which the driver moves the steering wheel.
EPS ECU LDW Safety Functionality	Component within the electronic power steering ECU responsible for keeping the lane departure warning action (oscillating torque) below Max_Torque_Amplitude and Max_Torque_Frequency. This component is also responsible for ensuring that the lane departure warning by means of vibration of the steering wheel is only applicated when LDW_On is set.
EPS ECU LKA Safety Functionality	Component within the electronic power steering ECU responsible for ensuring that the lane keeping assistance is not forcing the car longer than Max_Duration to the center of the lane. This component is also responsible for ensuring that the lane keeping assistance by forcing the car to the center of the lane is only applicated when the lane boundaries can be detected reliably.
EPS ECU	Component within the electronic power steering ECU

Final Torque	responsible for ensuring that the single torque values from LDW, LKA are combined with the drivers original steering torque and sent to the motor.
Motor	Mechatronic device which adds extra steering torque directly to the steering wheel.

3.4. Allocation of Functional Safety Requirements to Architecture Elements

ID	Functional Safety Requirement	Electronic Power Steering ECU	Camera ECU	Car Display ECU
Functional Safety Requirement 01-01	The lane keeping item shall ensure that the lane departure oscillating torque amplitude is below Max_Torque_Amplitude.	**X**		
Functional Safety Requirement 01-02	The lane keeping item shall ensure that the lane departure oscillating torque frequency is below Max_Torque_Frequency.	**X**		
Functional Safety Requirement 02-01	The electronic power steering ECU shall ensure that the duration of the lane keeping assistance torque applied is less than Max_Duration.	**X**		
Functional Safety Requirement 03-01	The lane keeping item shall ensure that the lane departure warning by means of vibration of the steering wheel is only possible when LDW_On is set.	**X**		
Functional Safety Requirement 04-01	The electronic power steering ECU shall ensure that the lane keeping assistance torque is set to zero when the camera sensor ECU can’t reliably detect the lane boundaries.	**X**		
Functional Safety	The electronic power steering			

Requirement 04-02	ECU shall ensure that the lane keeping assistance functionality is deactivated and signalized on the car display when the camera sensor ECU can't reliably detect the lane boundaries.	**X**		

3.5. Warning and Degradation Concept

ID	Degradation Mode	Trigger for Degradation Mode	Safe State invoked?	Driver Warning
WDC-01	Turn off LDW functionality	Malfunction_01, Malfunction_02, Malfunction_04	Yes, LDW oscillating torque shall be set to zero	Lane assistance functionality set inactive and malfunction warning to the driver via car display.
WDC-02	Turn off LKA functionality	Malfunction_03, Malfunction_05	Yes, LKA added extra torque shall be set to zero	Lane assistance functionality set inactive and malfunction warning to the driver via car display.